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(54) **ELECTRICAL APPARATUS HAVING A GAS INSULATION CONTAINING A FLUORINATED COMPOUND**

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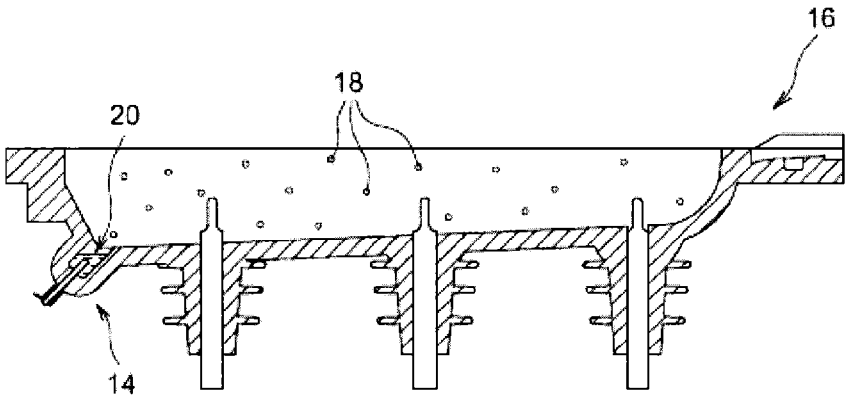
(57) **ABSTRACT**

An electrical apparatus for a medium- to high-voltage current transport line having a gas insulation including: a sealed housing filled with an electrically insulating gas including at least one fluorinated compound such as a fluoroketone, at least one electrical component arranged inside the inner space of the housing, and a mechanism regulating an amount of the fluorinated compound inside the inner space of the housing. The regulating mechanism includes a heater, heating a liquid resulting from condensation of the fluorinated product present in the insulating gas, to cause at least a portion of the liquid to vaporize.

18 Claims, 3 Drawing Sheets



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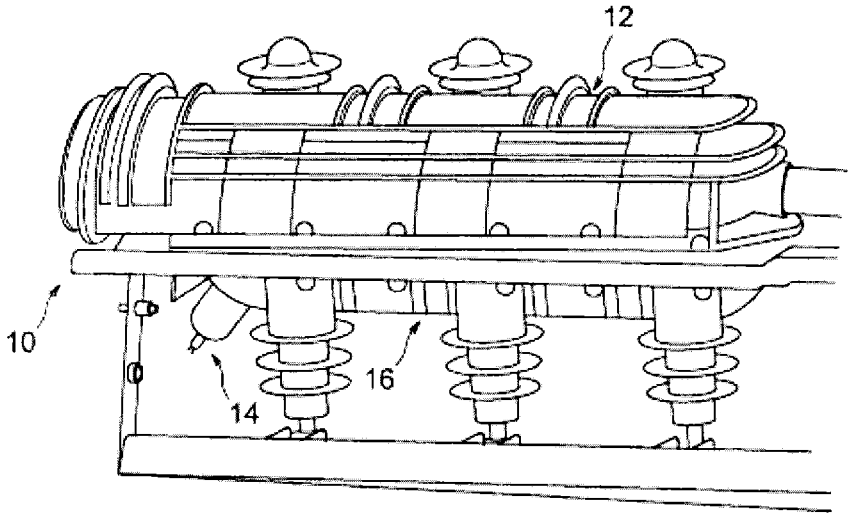

Fig. 1

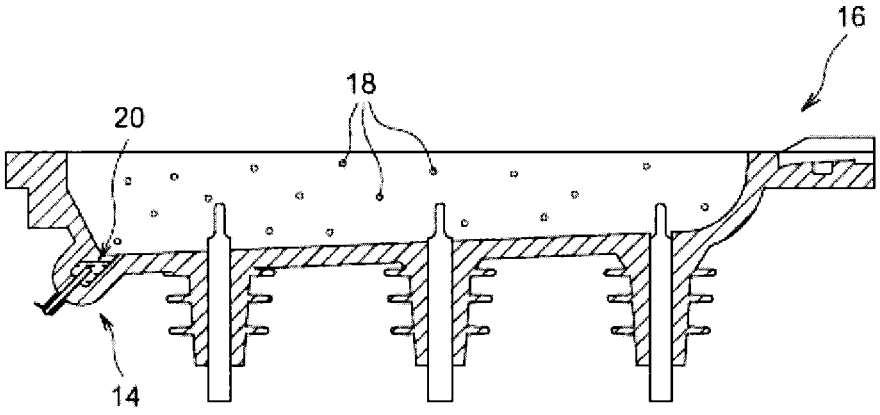

Fig. 2

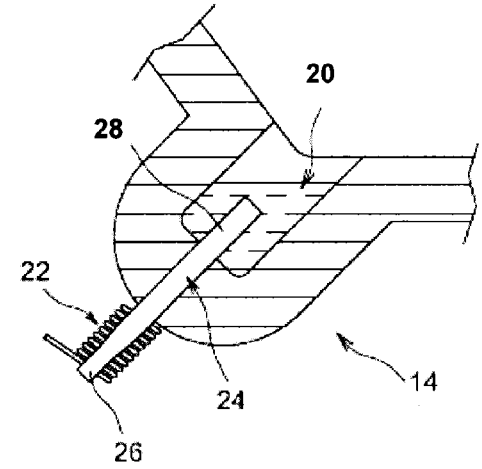

Fig. 3A

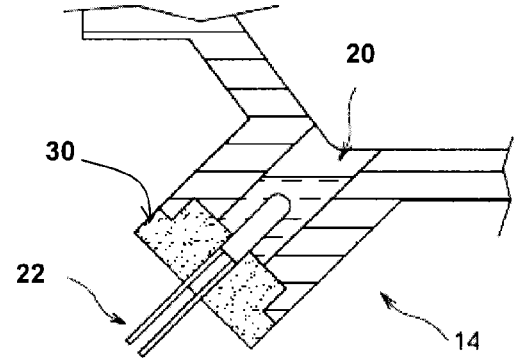

Fig. 3B

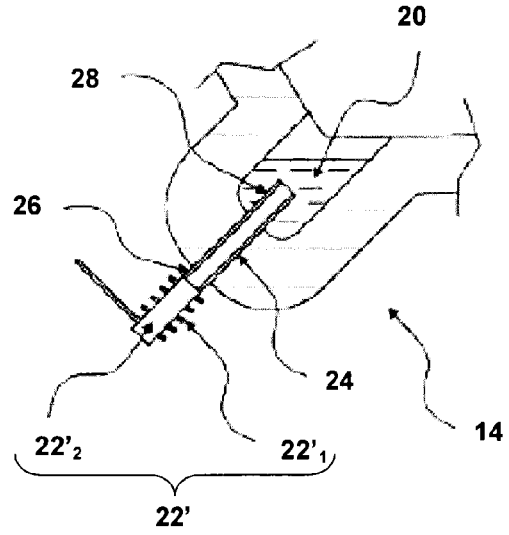

Fig. 3C

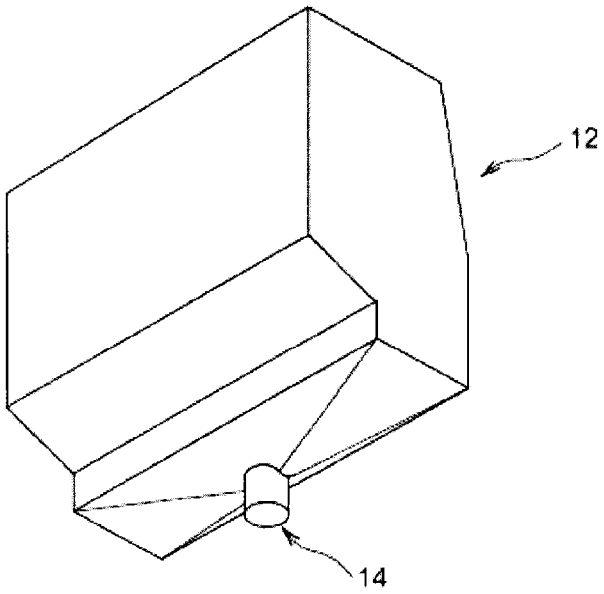

Fig. 4

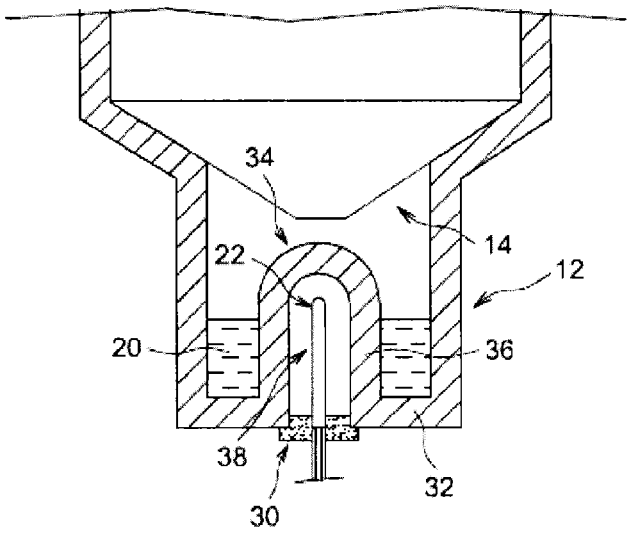

Fig. 5

ELECTRICAL APPARATUS HAVING A GAS INSULATION CONTAINING A FLUORINATED COMPOUND

TECHNICAL FIELD

The invention relates to an electrical apparatus having a gas insulation for a medium- or high-voltage power transmission line, which contains means for regulating the quantity of insulating gas in suspension in the inner space of the insulating housing.

PRIOR ART

In an electrical apparatus for medium- or high-voltages, the functions of electrical insulation and electric arc extinction are typically performed by an insulating gas that is confined inside the apparatus. In the generally accepted sense of the term, "medium-voltage" denotes a voltage that is greater than 1,000 volts AC and strictly greater than 1,500 volts DC, but that does not exceed 52,000 volts AC or exceed 75,000 volts DC, whereas the term "high-voltage" denotes a voltage that is strictly greater than 52,000 volts AC and greater than 75,000 DC.

According to one known embodiment, the insulating gas used inside these apparatuses contains sulphur hexafluoride SF_6. Although it has very good properties, especially dielectric and chemical properties, sulphur hexafluoride is harmful to the environment; its GWP ("Global Warming Potential") in particular is very high.

Fluoroketones have been proposed as a replacement for sulphur hexafluoride, as described for example in the document WO 2010/142346. Fluoroketones have a good dielectric strength and better environmental characteristics than sulphur hexafluoride. Other fluorinated gases, used alone or in a mix, have also been envisioned due to their dielectric strength and their environmental characteristics, in particular hydrofluoroolefins (unpublished application FR 11 56062), hydrofluorocarbons, fluoro-oxiranes (unpublished application FR 11 60971), as well as hydrochloroolefins or hydrofluoroethers.

However, the boiling point of these fluorinated compounds is relatively high, especially as their molecule is large, particularly in the case of fluoroketone. Now, some electrical apparatuses are intended to be mounted outside, where the temperature may drop to negative temperatures as low as −40° C. Under such negative temperatures, it is possible to maintain the pressure of fluorinated gases, especially fluoroketones in gas form, only at a limited value, which reduces their effectiveness: in fact, at such temperatures, fluoroketone for example condenses, forming a liquid at the bottom of the housing.

The document WO2010/142346 describes an electrical apparatus containing means for regulating the pressure of fluoroketone gas. These regulating means contain means for injecting fluoroketone gas, and means for heating at least part of the outer housing of the apparatus; the partial heating of the housing makes it possible to heat the fluoroketone gas and to limit the condensation of the latter.

However, when the ambient temperature outside the housing is relatively cold, a large part of the heat produced to heat the housing is then exchanged with the outside, which translates into significant heat losses. Thus, such a system consumes a good deal of energy to heat the housing and the fluoroketone-based insulating gas.

SUMMARY OF THE INVENTION

The aim of the invention is to provide an electrical apparatus containing means for regulating the gas pressure of fluorinated gas while limiting losses of the produced heat.

The invention proposes an electrical apparatus having a gas insulation for medium- and/or high-voltages, containing a gas-tight housing the inner space of which is filled with an electrically insulating gas containing at least one fluorinated compound with a GWP below 3,500, notably a fluoroketone, a hydrofluoroolefin, a hydrofluorocarbon, and/or a fluoro-oxirane, or even a hydrochloroolefin or a hydrofluoroether. At least one electrical component is arranged in the inner space of the housing, which is made in such a way that a liquid formed by condensation inside the housing, and particularly from the fluorinated compound, is collected in a tank the inner space of which communicates with the inner space of the housing. The electrical apparatus also comprises means for regulating the quantity of fluorinated compound in the inner space of the housing, which regulating means contain means for heating a liquid resulting from the condensation of fluorinated compound present in the insulating gas.

The heating of the liquid formed by condensation causes it to vaporize and thus increases the gas pressure in the housing. Losses of the heat produced by the heating means are then limited, which improves the effectiveness of the means for regulating the pressure of the insulating gas.

For preference, the condensation liquid flows under gravity toward the tank, and the means for heating the liquid are arranged at least partly in the tank.

Notably, the heating means may contain a resistor making it possible to heat the inside of the tank; alternatively, the heating means contain a solenoid and a, preferably ferromagnetic, core making it possible to heat the inside of the tank.

In another embodiment, the heating means contain a heat conductor component that passes through the wall of the tank, part of the heat conductor being located outside the tank and another part of the heat conductor received inside the tank. For preference, said heat conductor consists in a tube enabling the inner space of the housing to be filled with insulating gas. The heat conductor is associated with means allowing its temperature to be modified, notably a resistor, respectively a solenoid and its associated core, arranged outside the tank and the housing, and which is capable of heating said part of the heat conductor which is located outside the tank; a part of the heat conductor, or of the tube, may be inside the means for modifying its temperature, notably inside the solenoid where suitable.

In another embodiment, the heating means are arranged in a cavity open toward the outside which protrudes upward in relation to a lower bottom wall of the tank. For preference, the inner space of the cavity is filled with a heat transfer fluid that is capable of conducting the heat produced by a resistor toward the wall of the cavity.

BRIEF DESCRIPTION OF THE DRAWINGS

Other features and advantages of the invention will become apparent on reading the following detailed description, the understanding of which will be assisted by referring to the appended figures, among which:

FIG. **1** is a schematic representation in perspective of an electrical apparatus containing regulating means according to the invention;

FIG. **2** is a section along a vertical longitudinal plane from the bottom of the housing in FIG. **1**;

FIGS. **3**A, **3**B and **3**C are larger-scale details of the tank shown in section in the FIG. **2**, showing three embodiments of the heating means;

FIG. **4** is a schematic representation in perspective of another embodiment of the housing;

FIG. **5** is a section of the tank represented in FIG. **4**, showing another embodiment of the heating means.

DETAILED DESCRIPTION OF PARTICULAR EMBODIMENTS

The electrical apparatus shown in FIG. **1** is a disconnector switch, allowing the switching on and off of a power transmission line with a medium- and/or high-voltage; other types of apparatus and/or geometry for disconnector switches may of course be considered for the invention.

The apparatus **10** in particular contains an outside housing **12** with a longitudinal main axis delimiting a hollow space in which an electrical component (not shown) is arranged. The inner space of the housing **10** is sealed in a gas-tight manner and is filled with an electrically insulating gas with a GWP of preferably less than 85%, or 95%, or even 99% of that of SF_6. In particular, the dielectric insulating gas comprises a fluorinated compound with a GWP of less than 3,500, alone or in a mix, chosen in order to have the best insulating qualities, while also having a high enough saturated vapor. In the detailed embodiment, the housing is filled with a gas comprising at least one fluoroketone, but alternatively, this could be a hydrofluoroolefin such as HFO 1234 zeE and HFO 1234 yf, or even HFO 1336 mzzzM, a hydrofluorocarbon such as HFC R-125 or HFC R-236cb, and/or a fluoro-oxirane such as C_4F_8O, as well as a hydrochloroolefin such as HCFO trans 1233zd or hydrofluoroethers such as HFE 245fa.

The performance of an insulating gas such as a fluoroketone is all the more important when its molecule is large, i.e. when it contains a large number of atoms of carbon and fluorine, and when the molecule is branched. On the other hand, the larger the fluoroketone molecule, the higher its boiling point, i.e. its saturated vapor pressure at a given temperature is low. For example, the boiling point of the molecule $C_5F_{10}O$ is about 22° C., the boiling point of the molecule $C_6F_{12}O$ is about 49° C. and the boiling point of the molecule $C_7F_{18}O$ is about 73° C. Consequently, at a given temperature, the insulating gas may contain a larger quantity of a fluoroketone having a small molecule than of a fluoroketone having a larger molecule, but the arc extinction capacity of this smaller molecule is poorer.

When the apparatus **10** is used outdoors, as a consequence of the relatively low ambient temperature, part of the fluorinated product present in the insulating gas condenses, then reducing its partial pressure in the insulating gas and then reducing the effectiveness of the gas insulation. To maintain the partial pressure of the fluorinated compound used at an adequate level, the apparatus **10** thus contains means for regulating the pressure of the insulating gas inside the housing **12**, and in particular heating means to compensate for the condensation of fluoroketone and to maintain it in gaseous form.

According to the invention, the regulating means consist of means for recovering in a given place the liquid resulting from the condensation of the insulating gas, and for gathering it in a tank **14**. In the following description, the term "condensate" will be used to define the liquid resulting from the condensation of the insulating gas.

According to the preferred embodiment of the invention, the housing **12** of the apparatus **10** is made in such a way that the condensate flows under the Earth's gravity, and is recovered by a tank **14** toward which the condensate is caused to flow. In particular, in the embodiment in FIGS. **1** and **2**, the bottom **16** of the housing **12** is concave and open toward the top; the lower surface of the bottom **16** is rounded and the bottom **16** is inclined with respect to the horizontal, in such a way that the condensate **18**, which has flowed toward the bottom, also flows toward a longitudinal end of the bottom **16** of the housing **12**. As a consequence, all the droplets of condensate **18** converge under gravity on a lower longitudinal end part of the bottom **16** of the housing.

The tank **14** according to the invention is arranged at the level of this longitudinal end of the bottom **16** so that the condensate **20** thus gathered drains into the tank **14**. Thus, the tank **14** is located in a vertical position lower than the lowest point of the bottom **16** of the housing **12** and the tank **14** is open toward the top. The tank **14** is made in such a way that its inner space communicates directly with the inner space of the housing **12**.

In FIG. **4** another embodiment of the housing **12** is shown in which all the walls are overall flat and inclined downward. The tank **14** is then located at the lower vertical end of the housing **12** and centered horizontally with respect to the housing **12**. Thus, the walls of the housing **12** are all oriented in the direction of the tank **14** in such a way that the droplets **18** of condensed fluoroketone flow into the tank **14**. Other alternatives are possible.

The housing **12** itself is made of a thermally insulating material, which makes it possible to limit the effects of outside weather conditions (FIG. **1**). Alternatively, to reduce the total cost of the apparatus **10**, the housing **12** may be made from a thermally conductive material, for example from metal (FIG. **4**).

The electrical apparatus **10** also contains means for regulating the pressure of the insulating gas in the inner space of the housing **12**. These regulating means contain means (not shown) for measuring the quantity of fluoroketone present in the inner space of the housing **12**, which consist for example in at least one pressure sensor, means for measuring the density of fluoroketone or means for measuring the temperature of the insulating gas.

The regulating means also contain heating means making it possible to cause a vaporization of fluoroketone in the inner space of the housing **12**. These heating means are controlled as a function of the quantity of fluoroketone measured by the measuring means defined above. The heating means are made in such a way as to heat only the condensate **20** which is recovered in the tank **14**. Thus, the heating means trigger a vaporization of the condensate **20** collected in the tank **14**, thus producing an increase in the quantity of fluoroketone in gas form present in the insulating gas.

In a first embodiment illustrated in FIG. **3**A, the heating means contain a resistor **22**, for example an electrical resistor, which produces heat that is transmitted to the condensate; the heat produced by the resistor **22** is transmitted to the condensate by way of a heat conductor **24**. This transmission of heat is particularly advantageous in the case where the housing **12** is made of thermally insulating material, because only the heat conductor **24** allows the heat produced by the resistor **22** to reach the condensate **20**. It will nonetheless be understood that the heat conductor **24** may also be used for the embodiment in which the housing **12** is made from a thermally conductive material.

The resistor **22** is thus arranged outside the tank **14**, preferably outside the housing **12**, and the heat conductor **24** passes through the wall of the tank **14**. A first end **26** of the heat conductor is located outside the housing **12** and is heated by the resistor, and a second end **28** of the heat conductor **24** is located inside the tank **14** and heats the condensate **20**: the heat produced by the resistor is transmitted to the condensate **20** by way of the heat conductor **24**.

The heat conductor **24** may be a tube used to fill the inner space of the housing **12** with insulating gas. This makes it possible to make a single aperture in the housing **12** in order to perform two functions, thus reducing the risks of gas leaks as well as the total cost of the apparatus **10**.

In a variant illustrated in FIG. **3**B, the resistor **22** is received directly in the tank **14**. It may also be noted that the tank **14** consists in a cylindrical element the lower axial end of which is sealed in an gas-tight manner by a cork **30** which carries the resistor.

In a second embodiment shown in FIG. **3**C, the heating means **22'** comprise a solenoid $22'_1$ and its core $22'_2$. The heat produced is transmitted to the condensate **20**, preferably by a way of a heat conductor **24**, which may also be a filling tube: the solenoid $22'_1$ and its core $22'_2$ are thus arranged outside the tank **14**, outside the housing **12**, and the heat conductor **24** passes through the wall of the tank **14**, a first end **26** of the heat conductor **24** being located outside the housing **12** and heated by the means **22'**, and the second end **28** located inside the tank **14** heating the condensate **20**. Thus, the heat produced by the solenoid and its core is transmitted to the condensate **20** by way of the heat conductor **24**.

In another embodiment illustrated in FIG. **5**, the tank **14** of condensate **20** contains a lower bottom wall **32** in which a cavity **34** is made. The cavity **34** protrudes vertically upwards with respect to the bottom wall **32**: it therefore extends into the inside of the tank **14**. The cavity **34** is open toward the bottom and is made in such a way that its inner space does not communicate with the inner space of the tank **14**. A resistor **22** for heating the condensate **20** is arranged inside the cavity **34**, remote from the walls **36** of the cavity **34**. A cork **30** blocks the lower opening of the cavity **34** in a gas-tight manner, and carries the resistor **22**. The space separating the resistor **22** from the walls of the cavity **34** is filled by a heat transfer fluid **38** that transmits the heat produced by the resistor **22** to the walls **36** of the cavity.

This embodiment is particularly suited to a housing **12** the walls of which are made of a thermally conductive material. Thus, the walls of the tank **14** and the walls of the cavity **34** are also made of a thermally conductive material in order to conduct the heat, which is produced by the resistor **22**, coming from the heat transfer fluid **38** toward the fluoroketone condensate **20**. The heat thus transmitted toward the fluoroketone condensate **20** then vaporizes, to increase the pressure of the insulating gas.

By way of a variant embodiment, the means for heating the condensate **20** consist in means using magnetic and/or electric fields inside the electrical apparatus **10**, which means makes it possible to have no external power source, the apparatus **10** is then autonomous as regards the heating of the condensate **20**. Heat pipes or capillary evaporators could also be provided.

The electrical apparatus according to the invention is particularly advantageous due to the fact that a small proportion of the inner space of the housing **12** is heated by the heating means. These heating means therefore consume a small quantity of energy.

The invention claimed is:

1. An electrical apparatus having a gas insulation for medium- and/or high-voltages, comprising:

a gas-tight housing including an inner space filled with an electrically insulating gas including at least one fluorinated compound with a global warming potential GWP below 3500;

at least one electrical component arranged in the inner space of the housing;

a regulator configured to regulate a quantity of the at least one fluorinated compound in the inner space of the housing; and

a tank including an inner space directly communicating with the inner space of the housing, the inner space of the tank being seamlessly connected to the inner space of the housing, wherein

a bottom of the housing is inclined with respect to a horizontal axis of the housing,

a lower surface of the bottom is rounded,

the tank is arranged at a longitudinal end of the bottom and located in a vertical position lower than a lowest point of the bottom,

the housing and the tank are configured such that liquid formed by condensation of the fluorinated compound present in the insulating gas is collected in the tank, and

the regulator includes a heater configured to heat the liquid resulting from condensation of the fluorinated compound present in the insulating gas, to cause vaporization of at least part of the liquid.

2. The electrical apparatus according to claim **1**, wherein the heater is arranged at least partly inside the tank.

3. The electrical apparatus according to claim **2**, wherein the heater includes a resistor configured to heat the inner space of the tank.

4. The electrical apparatus according to claim **2**, wherein the heater includes a solenoid having a solenoid core configured to heat the inner space of the tank.

5. The electrical apparatus according to claim **2**, wherein the heater includes a heat conducting component that passes through a wall of the tank, a first part of the heat conducting component being located outside the tank and a second part of the heat conducting component being located inside the tank.

6. The electrical apparatus according to claim **5**, wherein the heater includes a resistor, arranged outside the tank and outside the housing, configured to heat the first part of the heat conducting component located outside the tank.

7. The electrical apparatus according to claim **5**, wherein the heater includes a solenoid/core assembly, arranged outside the tank and outside the housing, configured to heat the first part of the heat conducting component located outside the tank.

8. The electrical apparatus according to claim **5**, wherein the heat conducting component includes a tube allowing the inner space of the housing to be filled with the insulating gas.

9. The electrical apparatus according to claim **1**,

wherein the tank includes a lower bottom wall forming a cavity open toward the outside and that protrudes toward the inside of the tank, and

wherein the heater is arranged in the cavity and includes at least a wall made from a conductive material.

10. The electrical apparatus according to claim **9**, wherein the inner space of the cavity is filled with a heat-transfer fluid, the heater being remote from the wall of the cavity.

11. The electrical apparatus according to claim **10**, wherein the heater includes a resistor or a solenoid/core

assembly remote from the wall of the cavity, the heat transfer fluid being constituted so as to transfer heat produced toward the wall.

12. The electrical apparatus according to claim **1**, wherein the fluorinated compound is chosen from fluoroketones, hydrofluoroolefins, fluorooxiranes, hydrofluorocarbons, or a mix of these compounds.

13. The electrical apparatus according to claim **1**, wherein the housing is formed such that the liquid flows under gravity toward the tank.

14. The electrical apparatus according to claim **1**, wherein the electrical apparatus is a disconnector switch configured to switch on and off a power transmission line associated with the at least one electrical component.

15. The electrical apparatus according to claim **1**, wherein the housing has a bottom surface, at least a portion of the bottom surface of the housing being sloped toward an opening to the tank.

16. The electrical apparatus according to claim **1**, wherein the tank is positioned only at a first end of the housing.

17. The electrical apparatus according to claim **1**, wherein the heater is configured to heat only the condensate.

18. An electrical apparatus having a gas insulation for medium- and/or high-voltages, comprising:

a gas-tight housing including an inner space filled with an electrically insulating gas including at least one fluorinated compound with a global warming potential GWP below 3500 chosen from fluoroketones, hydrofluoroolefins, fluorooxiranes, hydrofluorocarbons, or a mix of these compounds, and formed such that the liquid flows under gravity toward a tank;

at least one electrical component arranged in the inner space of the housing;

a regulator configured to regulate a quantity of fluorinated compound in the inner space of the housing; and

the tank including an inner space communicating with the inner space of the housing, the inner space of the tank being seamlessly connected to the inner space of the housing, wherein

a bottom of the housing is inclined with respect to a horizontal axis of the housing,

a lower surface of the bottom is rounded,

the tank is arranged at a longitudinal end of the bottom and located in a vertical position lower than a lowest point of the bottom,

the housing and the tank are configured such that liquid formed by condensation of the fluorinated compound present in the insulating gas is collected in the tank, and

the regulator includes a heater configured to heat the liquid resulting from condensation of the fluorinated compound present in the insulating gas, to cause vaporization of at least part of the liquid.

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